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FLIGHT MECHANICS OF PHOTON ROCKETS

By

Professor Eugen Saenger
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Stuttgart, West Germany

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

Photon-propelled rockets have exhaust velocities equal to that of light. From the laws of classical mechanics, it would seem that limited human lifetimes and the limited mass ratios of rockets would permit a range in space only the order of 0.1 lightyear. However, relativistic mechanics indicate that at these velocities a time dilatation occurs on board so that to the crew members the vehicle seems to be moving at a velocity greater than that of light, thus the range can be extended to extragallactic space.

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(Translated by Ruth von Saurma)

SCIENCE AND TECHNOLOGY SECTION
SPACE SYSTEMS INFORMATION BRANCH

PREFACE

This article appeared originally in Astronautica Acta, Vol. III, No. 2, 1957. Professor Saenger, and his wife Dr. Irene Sanger-Bredt, are both well known for their research and studies in rocket propulsion systems. During World War II, Dr. Saenger proposed an antipodal bomber that could be boosted by rocket power above the Earth's atmosphere. It would then circumnavigate the globe by skipping off the top of the atmosphere and rebounding into space. He has long been a proponent of photonic propulsion, and at the Seventh Congress of the International Astronautical Federation, in 1956, described a spacecraft that could reach Andromeda in 25 years and cross the universe in 41.9 years, from the space traveler's concept of time. (The same time, viewed from Earth, would be about 3×10^{12} years.)

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In keeping with the present state of art, the word "astronautics" - which means voyage to the stars - is commonly used in a quite limited sense to cover the field between aviation and space travel as well as the problems of extraterrestrial stations. Even today the mere discussion of interplanetary flight still puts the scientist into the category of dreamers. It is the same risk that he ran 25 years ago when talking about supersonic flight, high altitude rockets, or artificial earth satellites. So far only a few independent minds have risked the same fate as Giordano Bruno by discussing the true meaning of the bold word "astronautics", the flight to the fixed stars. However, it is now time to take courage and to conduct a survey of future possibilities which will enable us to steer a reasonable course in our technical development.

In their nuclear reactors our modern physicists have succeeded in producing mass radiation of various heavy particles with velocities approaching light velocity. They also succeeded in producing artificially stationary plasma temperatures of such a degree that the radiation pressure of these hot gases attain technical magnitude. Our modern rocket engineers closely follow the footsteps of the physicists in order to use this radiant energy for their jet propulsion systems and are supported by the rapidly developing technology of nuclear energy.

We know exactly what a modest mass ratio a rocket needs in order to reach a flight velocity that equals the exhaust velocity of its propulsive jet. Therefore, we also see the not too remote possibility that the flight velocity of a rocket ship in space can approach light velocity which brings the problem of reaching the fixed stars into the reach of technical feasibility.

Astronomers usually indicate the distances of the fixed stars in light years. For example the distance to the "Proxima Centauri", the star closest to the Sun, is approximately 4.3 light years; the distance to the center of the Milky Way is about 30,000 light years, to the Andromeda Nebulae 750,000 light years. It is estimated that the entire Universe extends over a distance of several billions of light years. According to more recent estimates, the last three figures even have to be doubled.

Relative to the Earth our spacecraft can at best attain an end velocity close to the velocity of light. Thus, it may seem at first that the human life span would limit the possible route of the craft to several light decades or to a small section of our Milky Way System in the immediate neighborhood of our Sun. And, assuming a complete conversion of the entire fuel mass, we would expect that the ultimate technical perfection of our rocket propulsion systems would enable us to reach the closest fixed stars of our solar environment, but the farther regions of our galaxy and extra-galactic spiral nebulae would forever remain inaccessible to us.

It is the objective of my speech to show you that actually this limitation does not exist at all, that the nominal life span of the crew of the spaceship is indeed adequate to reach any astronomical distance, not only within other galaxies but also to the very limits of the Cosmos; that the spaceship apparently can travel with multiple superlight velocity and that the required mass ratio of the rocket will be high but still conceivable. The reason for these astonishing facts is that for the flight mechanics of these space vehicles the classic laws of Newton are no longer valid and that the laws of Einstein's relativity theory apply.

Let us assume the ultimate case of a spacecraft with complete mass radiation where the entire onboard fuel supply will be completely converted into photons or neutrons, anti-neutrons, gravitons, etc., and expelled with light velocity into a predetermined direction.

Based on these calculations we can later easily determine other cases with mass-energy conversion factors other than one, that is for nuclear disintegration, nuclear fission, nuclear synthesis, etc. with lower exhaust velocities and higher mass ratios.

We further assume that such a rocket ship - for example with photon propulsion - travels through empty space in a straight line without the interference of any gravity field, and we also disregard the drag factor of interstellar gas.

Considering a coordinate system, or so-called "eigen" system, firmly connected with the vehicle, we use the well known classic fundamental rocket equation between the ratio m_e/m_{e0} of the initial "eigen" mass of the vehicle and the ratio of an attained "eigen" flight velocity v_e to the exhaust velocity c, which in this ultimate case also equals the light velocity.

$$m_e/m_{e0} = e^{-v_e/c} \qquad (1)$$

We use the expression "eigen velocity" for the parameter v_e to indicate that it does not represent a true velocity in the physical sense.

The numerical deviation of this parameter v_e from the true relative velocity v of the space craft to the Earth is no longer negligible, as soon as the flight velocity v is higher than approximately 10% of the light velocity. Therefore we are not astonished to determine according to equation 1 that for $m_e/m_{e0} = e^{-1}$ the proper flight velocity becomes equal to the light velocity, and for $m_e/m_{e0} = e^{-10}$ corresponds to the decuple light velocity, etc.

Nevertheless we shall try to better understand the nature of this strange "eigen" velocity v_e by measurements onboard the ship.

Let us assume that the crew has the usual chronometer onboard and measures the "eigen"time elapsed since starting the powered flight

$$t_e \tag{2}$$

Let us further assume that they also have onboard the normal accelerometers of the small spring-mass type and can measure their "eigen" acceleration

$$b_e \tag{3}$$

With these two values the crew can determine its "eigen" velocity v_e in the usual manner

$$v_e = \int_0^{t_e} b_e \, dt_e \tag{4}$$

The result of this calculation will correspond to the calculation of the velocity v_e attained by the propulsion according to equation 1; and again after some time the crew will find out that v_e exceeds the light velocity.

The crew can even evaluate further the two onboard measurements and determine a covered "eigen" flight path s_e

$$s_e = \int_0^{t_e} \int_0^{t_e} b_e \, dt_e \, dt_e = \int_0^{t_e} v_e \, dt_e \tag{5}$$

which is as fictive as the concept of the "eigen" velocity, which represents, however, a magnitude for the fuel consumption m_e/m_{e0} of the rocket ship.

The crew members do not have to doubt their own instrument recordings, because as an example they can check the chronometer with their own pulse beating and with the entire cycle of their normal life rhythm; and they will definitely feel physiologically the "eigen"-acceleration; in fact they will even try to control a constant "eigen" acceleration of the craft, if possible at a rate of $b_e = g = 9.81\ \mathrm{m/sec}^2$, the most comfortable rate to which they have been used on the Earth.

In this case where b_e = constant, the derived measurements of the "eigen" velocity v_e and the "eigen" flight path s_e can easily be determined

$$v_e = b_e\ t_e \tag{6}$$

$$s_e = b_e\ t_e^2/2 = v_e^2/2b_e \tag{7}$$

by means of the well known classical relation of steadily accelerated motion.

Of course, such a flight will be carefully observed and tracked by numerous instruments on the ground, and perhaps it will be agreed upon to exchange the data between ground observers and crew at certain intervals, maybe after a certain fuel consumption characterized by m_e/m_{e0}.

Gradually, considerable discrepancies will be found between the recordings of ground stations for the elapsed time t, the acceleration of the craft b, the flight velocity v, and the flight path s, and the corresponding onboard data of t_e, b_e, v_e, and s_e obtained by the crew without consideration of the environment.

After a certain series of data has been recorded, we will notice that the following well known relativistic relations for arbitrary "eigen" accelerations exist between the data recorded by ground observers and the crew:

$$v/c = \frac{1 - (m_e/m_{e0})^2}{1 + (m_e/m_{e0})^2} = \tanh\ (v_e/c) = \tanh\ (-\ln m_e/m_{e0}) \tag{1a}$$

$$dt/dt_e = \cosh\ (v_e/c) \tag{2a}$$

$$b/b_e = \cosh^{-3}\ (v_e/c) \tag{3a}$$

$$ds/ds_e = (\sinh\ v_e/c)\Big/(v_e/c) \tag{5a}$$

Hidden behind these harmless relations is the entire mystic experience of the spaceship crew. Its full impact, however, will be felt only if such flight velocities v approach the electromagnetic signaling speed c, where consequently all communication between ground stations and crew is lost and an immediate comparison of the different data is no longer possible.

In gravity- and drag-free space almost no limits are imposed on the ratio m_e/m_{e0} between end and initial mass of the spacecraft, especially when the fuel to be converted consists of solid and self-supported bodies which will only be consumed during the course of years. Therefore, Figure 1 shows first the m_e/m_{e0} ratio in wider ranges versus the resulting relations of the "eigen" velocity v_e or the relative velocity v to the light velocity c, according to equation 1 or 1a. We shall refer to these relations as Einstein numbers of space flight in analogy with the Mach numbers of atmospheric flights.

While the "eigen" Einstein numbers can assume values above 1, the relative Einstein number naturally approaches 1 without ever attaining it. This already shows the practical convenience of selecting an "eigen" velocity which prohibits that Einstein numbers in the considered ranges take completely inexplicable numerical values when referring to the relative velocities.

Connected herewith is the fact that according to ground observations the acceleration of the craft b decreases much more rapidly than the "eigen" acceleration b_e which the onboard crew experiences. For example, while for a constant "eigen" acceleration b_e the "eigen" velocity v_e increases proportionally to the "eigen" time t_e, the relative velocity v of the craft hardly increases at all for the ground observer since it approaches asymptotically the velocity of light.

Even more strange are the time and distance ratios when comparing them from the view point of ground observer and crew. Figure 1 illustrating the ratio dt/dt_e of the ground observer time element versus crew time element according to equation 2a, shows that for $v_e/c = 18$ a year passes for the ground observer while the crew only experiences the lapse of a second.

For $v_e/c = 32$, a million years would pass on Earth and seem like a second to the spaceship crew.

What we call time on Earth would completely stop or not exist at all for an assumed inhabitant of a photon, where $v_e/c = \infty$ and $v/c = 1$. These beings would remain outside of our world, their time cycle would not have any relation to ours. Let us assume that a light quantum be sent from the Earth to a 10 light years distant star and immediately be reflected back to the Earth. It would return to the Earth after 20 years.

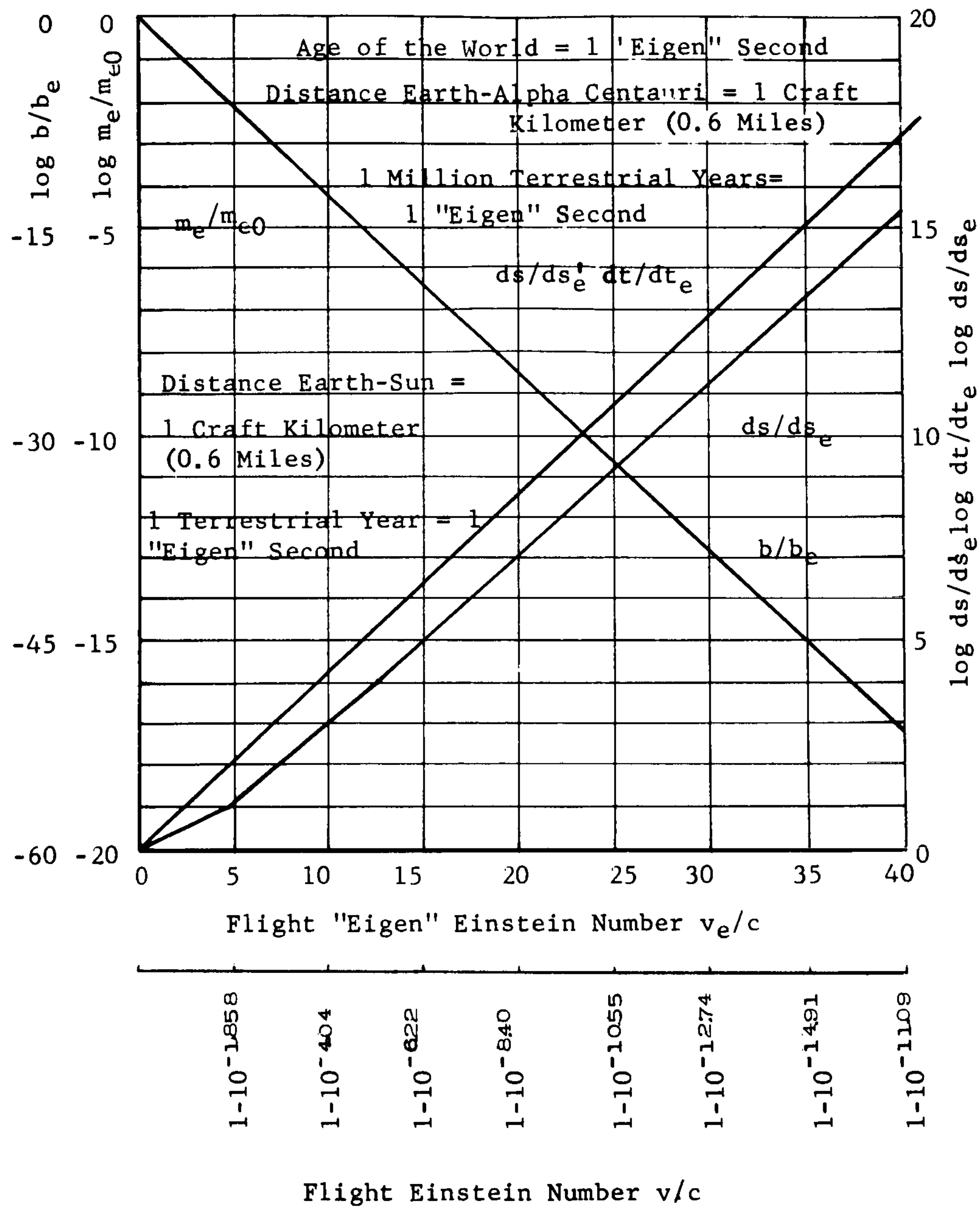

Figure 1. Adiabatic photon rocket. Ratio of obtained flight Einstein number v/c and flight "eigen" Einstein number v_e/c versus mass ratio m_e/m_{e0} and the ratios of relative velocity and "eigen" velocity b/b_e; of relative flight time to "eigen" flight time t/t_e; of relative flight path to "eigen" flight path ds/ds_e, and of the relative distances ds/ds_e from the Earth and from the craft.

However, for a passenger of this photon, no time at all would pass during this trip; the pendulum of this clock would not move at all and he would not have aged for a second. During the flight he would have the impression of moving with infinitely high velocity. Although the crew members of our spaceship can never completely attain this strange state of a photon inhabitant, they will approach it to a considerable extent when the flight attains high Einstein numbers. Indeed, for us earthlings, the life span of the crew reaches that of immortal gods; but the crew members do not have the impression to live any differently than they did on Earth and also will not become any older than they would have become on Earth. As to the flight paths ds and ds_e, another complication occurs in as much as we have to consider a third path measurement $ds_{e'}$.

The kinematical "eigen" values of the crew t_e, b_e, and the derived "eigen" values v_e and s_e are determined without any relation to the environment of the spacecraft, that is, without observing incidents outside the craft. Measurements of the relative values t, b, v, and s from the ground to the craft are taken by commonly used astronomical instruments.

If we assume that the crew has been provided with the same astronomical instruments and records t_e', b_e', v_e', and s_e' from the craft to the Earth, we are especially interested in the results of these measurements in relation to the previously discussed relative and "eigen" values.

Table 1 shows a summary of the entire kinematical parameter of the spacecraft:

Table 1. Kinematical Parameter of the Photon Craft

	"Eigen" Measurement Craft		Measurement Craft - Earth		Measurement Earth - Craft	"Eigen" Time - Velocity
Time	t_e	=	t_e'		t	
Acceleration	b_e		b_e'	=	b	
Velocity	v_e		v_e'	=	v	$v_{ez}=s/t_e$
Flight Path	s_e		s_e'	-	s	

We can immediately see that the recorded time t_e' is the same as our "eigen" time t_e, hence t_e'; and that the relative accelerations b_e' and relative velocities v_e' measured from the craft to the ground, have to be identical with the relative values b and v measured in opposite direction; thus $b_e' = b$ and $v_e' = v$, since apparently it does not matter whether the craft or the Earth is considered stationary and the other object in motion.

It is slightly different when we measure onboard the craft the length of a certain tract in the flight path which does not move in relation to the Earth, for example the distance s of the Earth from the target of the flight. Each element ds of this tract moves relative to the craft with the velocity v and thus is subjected to the relativistic length dilatation.

$$ds/ds_e' = (1 - v^2/c^2)^{-\frac{1}{2}} = \cosh \quad (v_e/c) = dt/dt_e \qquad (8)$$

Measured from the moving craft, the track stationary to the Earth appears shorter than the tract measured from the ground; the resulting ratio is the same as that of the different time measurements from both observation points.

Therefore, the ratio ds/ds_e of the distance measured by the ground observer and the distance measured by the crew, plotted in Figure 1 according to equation 8, is in analogy with the curve dt/dt_e and shows that for example for $v_e/c = 19$ an astronomical distance such as the one from the Earth to the Sun appears to the crew as only 1 kilometer (0.6 miles) long, and that for $v_e/c = 32$, the distance of our Sun to its closest neighboring sun, the Proxima Centauri, defined as being 4 1/3 light years by astronomers on the Earth, also amounts to only 1 kilometer (0.6 miles) for the crew of our spacecraft. These distances can be covered with the indicated "eigen" velocities in about 0.317×10^{-5} or 5.36×10^{-5} "eigen" seconds.

For the assumed inhabitants of a photon who - relative to us - travel on this light quantum with the velocity of light, all distances of our world would shrink to zero; these beings would actually live outside of our world.

If our assumed passenger could measure from his photon the length of his flight path that to us extends over 10 light years, he would gain the impression that during the time zero he would have covered the path zero. His world would be without any relation to ours. The crew of our spacecraft can never completely attain this strange state, but it can approach it at considerably higher "eigen" Einstein numbers of the flight.

The represented ratios of the relativistic time or length dilatation mainly disclose philosophical or even mythological aspects. However, a very concrete technical aspect of utmost importance is revealed when considering the ratio ds/ds_e of the astronomical distances s to the "eigen" paths s of the rocket.

Under all circumstances the astronomical distance s remains the basis for planning a space flight and also the index of its success. It would be completely unreasonable to replace s by the relative distance s_e' which depends on the flight velocity, mainly to avoid talking about flight velocities that are higher than the velocity of light.

Contrary herewith, the "eigen" path s_e is a completely fictive number without any physical importance; according to equations 1 and 5, however, it is an index for the required fuel consumption of the craft.

The ratio ds/ds_e of the two paths is plotted in Figure 1 as third curve which shows the immense increase in the astronomical distances in comparison with the "eigen" paths at higher Einstein numbers. Consequently, unlimited astronomical distances can be covered by finite "eigen" paths; and they only require finite fuel consumption.

Let us briefly consider only one of the many conceivable examples which can be deduced from the discussed kinematical fundamental relations: the flight covering an astronomical distance s; during the first half of the trip the craft be accelerated with constant "eigen" acceleration b_e; during the second half the craft be decelerated with equal "eigen" acceleration; and again interstellar drag be disregarded.

We can easily obtain the kinematical and dynamical flight ratios by an integration of the discussed fundamental relations, and especially the following values that are of interest to us: "Eigen" time of the entire flight t_e

$$t_e = \frac{2c}{b_e} \operatorname{arcosh} \left(1 + \frac{b_e s}{2c_2} \right), \tag{9}$$

or for $b_e s/2c^2 \gg 1$:

$$t_e \sim \frac{2c}{b_e} \ln \frac{b_e s}{c^2} = \frac{c}{b_e} \ln \frac{m_{e0}}{m_e} \quad . \tag{9a}$$

Required mass ratio m_e/m_{e0} of the craft

$$\frac{m_{e0}}{m_e} = \exp\left[2 \operatorname{arcosh}\left(1 + \frac{b_e s}{2c^2}\right)\right], \tag{10}$$

or for $b_e s/2c^2 \gg 1$:

$$\frac{m_{e0}}{m_e} \doteq \left(\frac{b_e s}{c^2}\right)^2 \tag{10a}$$

Optimum "eigen" Einstein number at midway distance

$$\frac{v_e}{e}_{max} = \operatorname{arcosh}\left(1 + \frac{b_e s}{2c^2}\right), \tag{11}$$

or for $b_e s/2c^2 \gg 1$:

$$\left(\frac{v_e}{c}\right)_{max} \doteq \ln \frac{b_e s}{c^2} = \frac{1}{2} \ln \frac{m_{e0}}{m_e} \tag{11a}$$

First of all equation 10a shows that for great distances at a given mass ratio the range s is inversely proportional to the used "eigen" acceleration b_e, that means low "eigen" accelerations are favorable to obtaining wide ranges. On the other hand it follows from equation 9a that the duration of the flight t_e also is inversely proportional to b_e; the flight time is increased in the same rate as the flight range at low "eigen" accelerations. The "eigen" time velocity $v_{ez} = s/t_e$ is independent from b_e.

The three discussed magnitudes are plotted in Figure 2 for $b_e = g = 9.81\ m/sec^2$, that means for an "eigen" acceleration equaling the normal Earth acceleration versus all conceivable astronomical distances s up to the assumed total distance of the Universe. They furnish plenty of material for future thoughts.

In order to enliven the abscissa, some definite astronomical distances are marked, for example the distance between two Earth antipodes (20,000 km = 12,000 miles), between Earth and Moon (400,000 km = 240,000 miles) between Earth and Sun (150 million km = 100 million miles), between our solar system and the closest one of the Proxima Centauri (4.3 light years), between Sun and the center of the Milky Way (30,000 light years), between Earth and the Andromeda Nebulae (approximately 750,000* light years), and finally the assumed total distance of the Universe (3* billion light years). As Figure 2 shows, under the assumptions made, the "eigen" flight times t_e for these seven trips vary between 47.2 minutes and 41.9 years.

The human life span would be sufficient to circumnavigate an entire static universe. However, whether our solar system would still exist upon the return of the crew, remains questionable, because in the meantime more than 3 billion years would have passed. During this time the crew stayed temporally almost outside our world system, hence in another world.

On this last trip the members of the crew will be inclined to compare the relative astronomical distance of 3 billion light years with the duration of their trip of 41.9 "eigen" years and will have the impression that they traveled with a mean velocity of 720 million times light velocity. Of course, also this "eigen" times velocity, the same as our "eigen" velocity, is no real physical velocity since we divide the astronomical distance measured in our Earth system by the "eigen" time of the flight measured in the craft. Nevertheless this "eigen" time velocity is a very suitable expression for the actual experience of the crew.

This "eigen" time velocity which can surpass million times the velocity of light, is of extreme practical importance, because it represents the connection of the flight distance ds measured by the Earth astronomer with the "eigen" time dt_e experienced by the crew, namely $v_{ez} = ds/dt_e$, and thus reflects the flight velocities experienced by the crew, which does not apply to v_e. However, the latter "eigen" velocity v_e better characterizes the fuel comsumption.

From Figures 1 and 2 we can see that for the most interesting velocity ranges $v_e/c = 10^0$ to 10^2 the value of the relative velocity v as well as of the "eigen" time velocity v_{ez} would lead to unuseable figures. In addition to its importance as index for the fuel consumption, this is another practical reason to use the term "eigen velocity" in spite of its physical absurdity. From a practical standpoint also the terms "eigen time velocity" and "super light velocity" are justified.

During the transition stage from a field of pure physics into applied physics or technology, new terms become necessary which quite often conform less with strict scientific definitions but meet the imperative demands of practical living and can be understood by wider circles. No doubt, these last requirements are of primary importance compared to scientific requirements if - as in the present case - an agreement cannot be reached.

* Studies by Walter Baade on Cepheid and Cluster Variables show that this figure is approximately doubled.

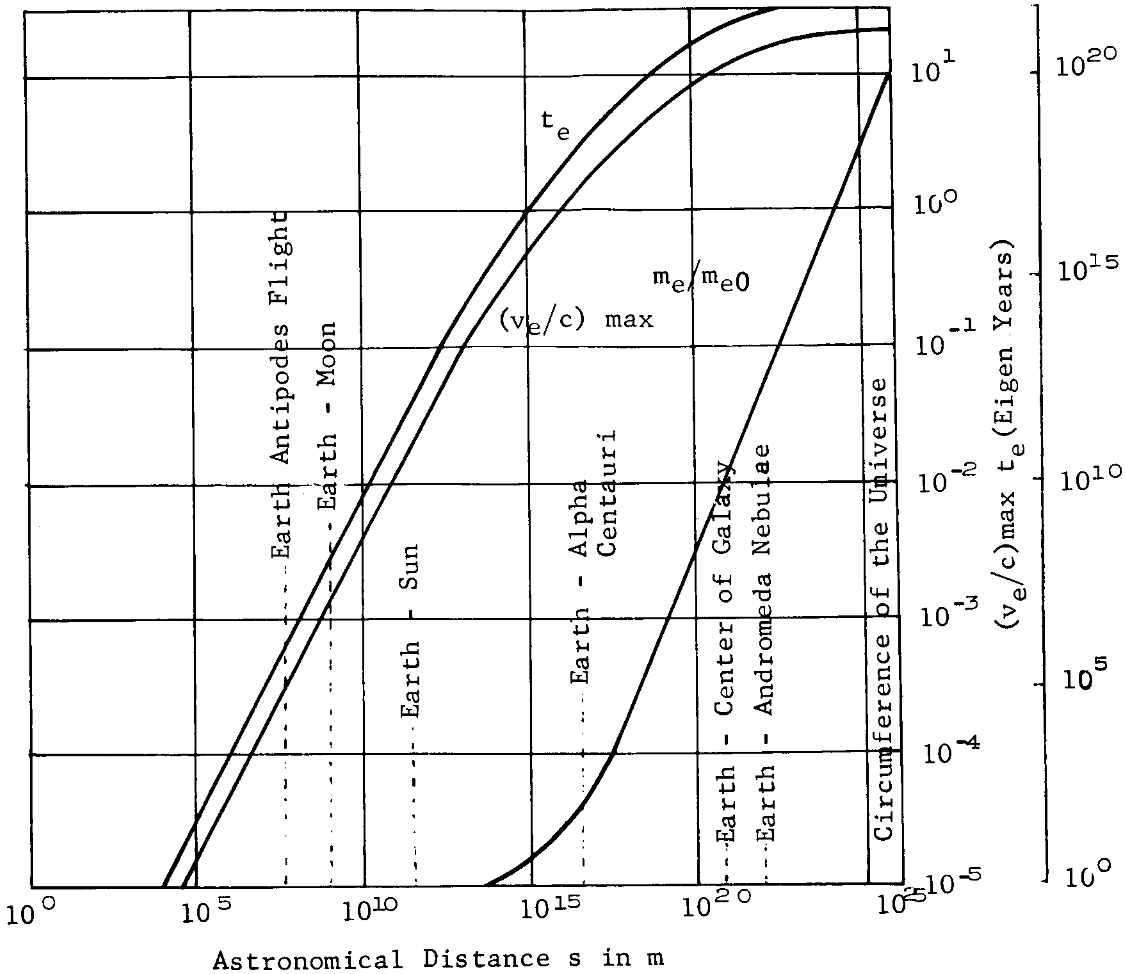

Figure 2. Adiabatic photon rocket. Flights with $b_e = 10$ m/sec^2 "eigen" acceleration until reaching half of the astronomical target distance s, and with $b_e=10$ m/sec^2 "eigen" deceleration during the second half of the distance; ratio of the required mass ratios m_{e0}/m_e, the entire "eigen" flight time t_e, and the highest "eigen" Einstein number at midway distance $(v_e/c)_{max}$ versus the entire astronomical distance s.

If we have no better measure than the astronomical distance of 750,000 light years for the distance from the Earth to the Andromeda Nebulae, and the members of the crew find out that they can cover this distance during 25 of their own life years, our present day language does not offer any better definition than saying that the flight velocity appears to the crew as 30,000 times light velocity.

These astonishing facts are in perfect agreement with practical physical experiments. The crew finds itself in a similar situation as the mesons which originate at the upper stratosphere limit through the impact of primary particles of cosmic radiation. Only due to the relativistic time dilatation, their short "eigen" life period suffices to penetrate the total remainder of the atmosphere and still to be registered by instruments on the Earth's surface.

According to the forementioned relations, the relative life path s of a μ-meson of the high altitude radiation with a life period t_e is:

$$s = vt = vt_e \ (1 - v^2/c^2)^{-\frac{1}{2}} = ct_e \sqrt{\frac{E_{kin}}{m_e c^2} \left(2 + \frac{E_{kin}}{m_e c^2}\right)} \qquad (12)$$

and offers the experimental proof for the relativistic time dilatations. At velocities close to light velocity the well known life period of the μ-mesons of approximately $t_e = 10^{-6}$ seconds would only permit a classical life path of approximately $s = c\ t_e = 3.10^8 \times 10^{-6} = 300$ m (1000 ft). Due to the high kinetic energies of approximately $E_{kin}/m_e c^2 = 10^2$, the relativistic life path is increased 10^2 times and extends according to the a/m relation from the upper stratosphere limit to the Earth's surface: the "eigen" time velocity of the mesons attains 10^2 times light velocity.

In the same way as the short life period of 10^{-6} seconds of the meson of the cosmic radiation orginating at the upper stratosphere limit with a relative velocity near light velocity, suffices to penetrate the entire width of the atmosphere of about 30 kilometers (18 miles) with hundred times light velocity as "eigen" velocity, the short human life span of less than hundred years suffices to circle the entire Cosmos extending over 3 billion light years with an "eigen" velocity of several hundred million times light velocity.

In a curve parallel to the above mentioned, Figure 2 further shows the highest "eigen" Einstein number of the flight occurring in the middle of the flight path. For a circumnavigation of the Universe, the highest "eigen" Einstein number is $(v_e/c)_{max} = 22$, and is very similar to the corresponding Mach number for an earth orbit of an artificial earth satellite.

According to Figure 1 this corresponds to a length dilatation of approximately $ds/ds_e' = 3 \times 10^9$, which means that for the crew the Universe at that moment would have a circumference of only about one light year. If the crew does not decelerate its velocity, the craft would circle the Universe once each "eigen" year - as long as all switches are properly set.

From the third curve m_{e0}/m_e in Figure 2 we can see that with complete mass radiation the fuel consumption in the diagram is only noticeable for trips considerably outside our Solar System. For a flight in the described but not at all most economical way to our closest neighboring solar system, the Proxima Centauri, the fuel mass at the end of the trip would have to be 40 times the mass of the spaceship; the trip would take about 3.6 "eigen" years or 6 terrestrial years for an astronomical distance of 4.3 light years.

For farther reaching expeditions the required mass ratios increase much faster than the required "eigen" flight times, but within the entire galactic region they still remain in a technically conceivable order of magnitude, especially if we consider even lower accelerations or a longer free-coasting flight phase.

In conclusion we have to state: To reach the fixed stars does not require the trips of generations during which various generations are born and raised and again pass away until the great grandchildren finally reach the goal set by their forefathers. It is neither true that due to our limited life span we cannot reach distant galaxies hundred thousand light years away from us nor that Nature would limit our activities to our small corner of the Universe. Definitely not! We do not have to resign ourselves to dutiful complacency. The infinite Universe is small enough to be penetrated to its very limits by our own individual efforts. Any place can be reached by man.

We are reminded of a favorite quotation by Einstein: "As cunning as our Lord may be, He never is mean."

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